A STAND GROWTH MODEL FOR YIELD PREDICTION IN RAINFORESTS: DESIGN, IMPLEMENTATION AND ENHANCEMENTS

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ABSTRACT

Growth models for yield forecasting should be deterministic and flexible enough to handle diverse inventory data. This review identifies techniques suitable for modelling tropical rainforests and describes essential characteristics of their component functions.

The Queensland rainforest growth model aggregates some 150 commercial tree species into twenty species groups based on growth habit, volume relationships and harvesting practices. Trees are grouped according to species group and tree size into cohorts, which form the basis for simulation. Equations to predict increment, mortality and recruitment were derived through linear regression.

Enhancements proposed for the model are described and suggestions are made for modifying the model for use in other tropical mixed/moist forests. The model is implemented as a Fortran-77 subroutine, comprising 160 lines of code. Copies of the subroutine are available from the author on request.

INTRODUCTION

The reliability of yield forecasts depends upon three major factors:

. Area estimates

. Inventory data

. Growth models

Other important factors include volume equations, prediction of stems removed in selection logging, and the incidence of defective stems. Much has been written about these aspects, but growth modelling in particular, has been subjected to rapid advances in theory and technology.

GROWTH MODELS FOR YIELD FORECASTING

The role of the growth model in yield forecasting is to update inventory data to provide a reliable (precise and unbiased) indication of what the forest stand will look like at some future date. As yield calculations may involve large amounts of inventory data, the growth model should be computationally efficient. The model may also be used to investigate different prescriptions for selection logging, silvicultural treatment, *etc.* To satisfy these requirements, a growth model should be:

- a stand growth model which predicts annual growth;
- deterministic (computationally more efficient than stochastic);
- modular to simplify alterations and enhancements;
- flexible enough to utilize various inventory data;
- useful for investigating alternative logging strategies.

Three broad categories of growth models exist: whole stand models, stand class models, and individual tree models. Whole stand models use parameters such as stocking, basal area and standing volume to predict the growth of the forest. This category includes various approaches ranging from simplistic growth percentages to more sophisticated equations. although the latter may give good results for even-aged monospecific stand, whole stand models provide forecasts which are too general to be of much use in mixed forests.

The most detailed approach is that of individual tree models which require details of every tree in the stand. Most of these models require diameter, and some also require the spatial position, tree height or crown class of trees. Many individual tree models for plantations have been published (Dudek & Ek 1980), but because of the difficulty of dealing with inventory derived from point sampling and with deterministic mortality, this approach is rarely used for natural forests.

Stand class models, intermediate between whole stand and individual tree models, can provide sufficient information for management of mixed forests without the complexity of individual tree models. Stand classes may comprise diameter classes, deciles or percentiles, or more flexible groups, and the models may be implemented as stand table projection, transition matrix or cohort models. This approach to stand growth modelling provides the greatest utility for yield forecasting in mixed forests.

Stand table projection

Stand table projection is a long established manual technique which is readily adapted to mixed forests and computers. The method uses the stand table, which is periodically and repeatedly updated to indicate the future stand condition. In monospecific forests, the stand can be represented as a single list of stem numbers within pre-determined diameter classes. However, in mixed stands, it is usually necessary to identify several stand fractions defined by species and/or merchantability.

Three variations exist. The first assumes that all trees in a diameter class are located at the class midpoint, and that all grow at the same rate. The method essentially involves projecting the class boundaries so that future classes contain the same trees. This approach introduces complications when several stand fractions, each with different growth rates, are identified.

The second method assumes that the trees in each diameter class uniformly distributed through the class and that each tree grows at the class average. For each class, a "movement ratio" determined from the class width and increment, indicates the proportion of trees moving to the next class. Bias may be introduced if the distribution of stems is not uniform, but may be minimized by employing a small class width. However, if too many stand fractions are created, the bias introduced by the assumption of a uniform distribution increases. Increment estimates may be drawn from a variety of sources: subjective guesses, hand drawn curves, continuous forest inventory (CFI) summaries and equations derived by linear regression can all be accomodated.

The method has been used extensively in Queensland, but has been abandoned because of restrictions inherent in the method.

The third approach accommodates some variation in the growth rate within any diameter class, by using the actual movement of trees rather than the assumed movement ratio. For example, the movement ratio might predict that 90% of the trees will move one class and 10% remain, whereas this method might predict that 20% will move two classes, 50% will move one class, and 30% will remain. This approach is more demanding of data, and can be more efficiently be modelled using matrices.

The principal advantages of stand table projection are that it is highly flexible and easily implemented. If the projection system is formulated as a computer program, the growth matrix can be presented as data, and is thus easily changed. Its disadvantages relate to the large number of parameters required, and the difficulty in accommodating growth variations to reflect site quality and competition.

Transition matrix models

The growth data employed in stand table projection can be compactly and efficiently represented as matrix, the stand table as a vector, and the projection process as matrix multiplication. This formal representation focuses attention on the inherent assumptions: that the probability of any event depends only on its initial state, and that probabilities do not change over time. These assumptions immediately highlight the weaknesses of the approach: competition cannot be accomodated readily, regeneration and mortality cannot be varied, and predictions must be an integer multiple of the remeasurement period. However, it is possible to overcome some of these restrictions (Harrison & Michie 1985).

One weakness, that of the large number of entries required to compile the transition matrix, can be partially overcome by selecting a projection interval sufficiently short that no tree can move more than one class during the period (Usher 1966). There are still a large number of parameters to be estimated, but if regularly remeasured CFI data are available, and span the range of forest types and densities, this may be a viable approach. It is easy to use, and is computationally efficient.

The Queensland Department of Forestry used this approach for some years. The system employed in Queensland entailed a database of CFI data, from which representative (of the stand to be projected) plots were selected and summarized into a transition matrix. A new matrix was compiled for each stand condition. Obviously, long projections lead to higher stand densities which require alternative matrices. This approach is useful where ample data is available, but has not been analyzed or incorporated into regression equations. It is an efficient means of summarizing data, but rarely leads to a understanding of the processes involved. Summarizing the data into regression equations requires a better understanding, and involves the estimation of fewer parameters.

Cohort models

Cohort models have similarities with the mean tree approach sometimes used for plantations. Groups or cohorts of trees of similar characteristics (species, size) are formed and within each group the growth of the mean tree is modelled. Thus for each cohort, the group identity (species, merchantability, *etc.*), the mean size and number of stems which may be fractional, is recorded and updated. Mortality reduces the number of stems within the cohort and recruitment creates new cohorts.

The efficiency of this approach depends on the initial formation and management of cohorts. Some models use equally sized classes (e.g. Gibson *et al.* 1969), some use equal numbers within classes (e.g. Clutter & Allison 1974, Alder 1979), while others have a more flexible approach (Leary 1979, Reed 1980). There is a trade-off between the number of classes and the precision of the forecast, especially in uneven-aged forests. This can be optimized by using cohorts with many stems for non-commercial species and non-merchantable sizes, and allowing the cohorts to divide when commercial stems reach merchantable sizes (Vanclay 1987).

With appropriate growth functions, cohort models can offer great reliability and flexibility for yield forecasting in mixed forests.

GROWTH FUNCTIONS REQUIRED

Most growth models require the inclusion of three types of functions: diameter increment, mortality and recruitment. Whole stand and transition matrix models have somewhat different requirements, but will not be further considered.

Diameter increment

An essential component of a growth model is the prediction of diameter increment. In monospecific stands, a robust approach is to predict the stand basal area increment and apportion this among the component trees (Vanclay 1985). However, in mixed stands, it is expedient to predict the increment of each individual stem. Increment can be predicted as diameter or basal area increment; theoretical (Vanclay 1983) and empirical (West 1980) analyses have confirmed that both approaches are equally efficient. The choice between these should be made on the basis of the distribution of residuals.

A suitable time interval should be selected to minimize the effects of climatic variation and of any measurement error. The interval should be sufficiently long to ensure a large increment relative to the measurement error. A period of five years appears to fulfill these requirements.

It is desirable to use equations which are inherently constrained to provide sensible predictions near the limits of the data, especially if data are sparse. Diameter increment equations should pass through the origin (or have a small positive intercept), should rise to a broad plateau, decrease and asymptotically approach zero or reach a sensible maximum diameter. Robust equations with such a shape include:

$$Log(DI) = a + b \times D + c \times Log(D)$$

$$DI = a \times D^{c} \times (D_{max} - D)$$

$$DI = a \times D \times \left\{ \left(\frac{D_{max}}{D} \right)^{c} - 1 \right\}$$

where DI is diameter increment, D is diameter, D_{max} is the maximum attainable diameter, and a, b, and c are parameters to be estimated. Although D_{max} can be estimated by regression, it is often expedient to provide a subjective estimate, especially if data for large trees are scarce. These equations provide the basic elements of increment functions; terms such as site quality and stand basal area should also be incorporated.

The first equation can be fitted by linear regression, the second with a few interations of linear regression, but the last equation requires non-linear regression. Although it is theoretically preferable to use generalized least squares (Ferguson & Leech 1978, 1981) for remeasured plot data, ordinary least squares can generally be used if the number of plots is large relative to the number of remeasurements.

A great variety of competition indices have been employed in plantation growth models, but appear to offer little advantage in mixed forests. Stand basal area is generally more useful than competition indices (Vanclay 1983). If an additional term is desired to reflect the relative position in the stand, the basal area of trees bigger than the subject tree is often effective.

Mortality

Mortality functions should predict natural regular mortality. Mortality arising directly from logging can be better accommodated through a logging damage function. Catastrophic mortality should not be included in a deterministic function, as it generally leads to an undesirable distribution of residuals and can be handled better in other ways (Hamilton 1980).

Many approaches have been devised for modelling mortality in even-aged monospecific stands, but the alternatives are greatly reduced for mixed stands. Threshold increment and limiting competition approaches have been widely used, but do not appear to provide robust results, and empirical methods offer more promise (Vanclay 1983).

Hamilton (1980) argues that it is inappropriate to estimate relative mortality using linear functions, and that a logistic function is more appropriate:

$$P = \{1 + e^{-f(x)}\}^{-1}$$

where P is the probability of survival, and f(x) is some suitable linear function. This has the advantage that survival over a n-year period can be predicted as the n th power of the annual probability. Mortality is derived as 1 - P.

To enable parameter estimation using linear regression, this equation can be expressed as

$$Log\left(\frac{P}{1-P}\right) = f(x)$$

In mixed forests, a linear function in tree diameter and stand basal area generally provides reliable estimates of mortality. Mortality arising indirectly from logging can be accommodated by including time since logging (or cyclone):

$$Log\left(\frac{P}{1-P}\right) = a + \frac{b}{DBH} + c \times SBA + \frac{d}{TSL}$$

where D is diameter, SBA is stand basal area and TSL is time since logging (or cyclone).

Recruitment

The need for a recruitment or regeneration model depends on the intended length of projection. If long projections are envisaged, prediction of recruitment is essential, as recruitment will influence stand basal area. A common and simple approach is to assume that there is a constant pool of regeneration which is replenished as stems are recruited into the larger stand fraction, and whose composition never changes. Other authors try to model recruitment more ex-

plicitly. For example, Hann (1980) predicted recruitment from site index, total stand basal area and basal area in the smallest size class.

Recruitment is critical to successful predictions from succession models (Shugart 1984) and it is intuitive to examine how these stochastic models deal with recruitment, even if their methods cannot be directly applied to deterministic yield models. Recurring themes are seed sources, leaf area indices, soil moisture, gap size and the nature of the substrate (mineral soil of leaf litter). For yield models, equivalent concepts are stand composition, stand basal area, site quality, basal area removed and time since logging.

The modelling of recruitments is influenced by inventory technique more than any other growth model component. If a large fixed area plot is used to measure all stems to a relatively small size limit, then the "constant pool" method may perform well, especially if stems smaller than the recruitment size were measured. In contrast, point sampling (probability proportional to size) is unlikely to provide a realistic indication of the species composition of the advance growth, and the constant pool method is likely to fail.

Some growth models employ regeneration sub-models to predict the growth of regeneration from seed until it is recruited into the main model (e.g. Ek & Monserud 1974, Vanclay 1985). This provides good predictions in some forest types, but may be an unnecessary complication in rainforests where seedling mortality is high and most of the stems colonizing gaps after disturbance exist prior to the disturbance.

THE QUEENSLAND RAINFOREST GROWTH MODEL

The rainforest growth model (Vanclay 1987) is the most sophisticated of the native forest growth models employed by the Queensland Department of Forestry. Yet despite the complex nature of the forest that it simulates, it is comparatively simple and is readily adapted to other forest types.

The rainforest growth model is a cohort model which admits a maximum of 200 cohorts for each stand. Initially, stems from the same species group and whose diameters differ by less than five millimetres are grouped into a single cohort. If necessary, greater differences are accommodated by forming groups of stems most similar in size.

During simulation, cohorts comprising more than a critical number of stems of exhibiting diameter increments exceeding five millimetres per annum may split into two new cohorts, one with 25% of the stems and 1.3 times the predicted current annual increment, and one with 75% of the stems and 0.9 times the predicted current annual increment. This reflects the skewed nature of increment commonly observed in rainforest stands. The critical number of stems varies with stem size, and is twenty stems per hectare for stems below 40 *cm* dbh (diameter at breast height, over bark), five stems per hectare for stems exceeding 40 *cm* dbh, and two stems per hectare for stems exceeding the normal merchantable size (50 to 100 *cm* diameter breast height or above buttressing depending upon species). The total number of cohorts is maintained below 200 by merging, within species groups, cohorts with the most similar diameters.

Grouping species

Because of the large numbers of tree species represented in tropical rainforests, it is clearly impractical to develop separate functional relationships for each tree species. To sensibly aggregate these species, it is expedient to employ three criteria, namely the volume relationship, logging practice and growth pattern. In the model, species groups are identified by a four digit

code, SVLG, where S represents the datum source (0 = inventory, 1 = predicted ingrowth), V = indicates the volume equation to be used (1 to 4), L = indicates the logging rule applicable (1 to 9 inclusive) and G = indicates the growth group. Five growth groups were identified on the basis of merchantability, size commonly attained and growth rate. Generally, group 1 (large, fast growing) contains gap opportunists, group 3 (small, fast growing) contains other pioneer and short-lived species, and groups 2 and 4 (slow growing) contain shade tolerant species. Practical necessity required the use of a single (fifth) group for all non-commercial species, as inventory identified only commercial and potentially commercial species, with most non-commercial species recorded as miscellaneous.

Diameter increment

Because of the vast amount of data, the disproportionate representation of smaller size classes, and to facilitate graphical analyses of the residuals, the data were grouped according to site quality, soil parent material, stand basal area and 5 *cm* dbh classes. Some cells were further grouped to enable the estimation of the variance within each cell. The mean dbh and stand basal area of each cell were used in the analysis, and site quality and soil parent material were included as dummy (0, 1) variables. Linear regression, weighted by the inverse of the variance, produced the following results (Figure 1):

$$DI_1 = (140\text{-}20TG - D)XD^{0.667}X(2.497 + 1.196\,SQ - 1.061\,BV - 0.02859\,SBA)X10^{-4}$$

$$DI_2 = (160\text{-}30TG - D)XD^{0.667}X(2.543 + 0.2737\,CG - 0.02902\,SBA)X10^{-4}$$

$$DI_3 = (120 - D)XD^{0.765\text{-}0.051TG}X(2.478 + 1.055\,SQ - 0.8328\,CG - 0.03364\,SBA)X10^{-4}$$

$$DI_4 = (110 - D)XD^{0.833 + 0.013TG}X(1.542 + 0.3924\,CG - 0.01741\,SBA)X10^{-4}$$

$$DI_5 = (170 - 40\,SA - 60TG - D)XD^{0.667}X(2.076 - 0.3831\,CG - 0.01894\,SBA)X10^{-4}$$

where DI_i is the dbh increment (*cm* yr^{-1} of growth group i, D is dbh (*cm*), SBA is stand basal area (m^2/*ha* of stems exceeding 20 *cm* dbh), SQ is 1 for good sites and 0 for poor sites, BV is 1 on Basic Volcanic parent material, CG is 1 on Coarse Granite parent material, SA is 1 on Sedimentary, Metamorphic and Acid volcanic parent material, and TG is 1 on Tully Granite parent material.

Mortality

Mortality is predicted from tree size and stand density:

$$P_1 = (1 + e^{5.899 - 6.039D^{-1} - 0.008392\,SBA})^{-1}$$

$$P_2 = (1 + e^{4.379 + 0.1010D - 0.0007908\,D^2 - 0.01477\,SBA})^{-1}$$

$$P_3 = (1 + e^{5.261 - 5.838\,D^{-1}})^{-1}$$

$$P_4 = (1 + e^{5.331 - 2.802\,D^{-1} - 0.004500\,SBA})^{-1}$$

$$P_5 = (1 + e^{4.894 - 1.764\,D^{-1}})^{-1}$$

where P_i is the annual probability of mortality within growth group i, D is dbh (*cm*) and SBA is stand basal area (m^2/*ha* of stems exceeding 20 *cm* dbh). The trend in growth group 2 contrasts

strongly to that of the other growth groups (Figure 2), but is not inconsistent with findings of other workers (e.g. Buchman *et al.* 1983).

Recruitment

As the minimum stem size measured in inventory has varied between 3 and 20 *cm* dbh, recruitment must be predicted at 20 *cm* dbh. However, data concerning stems less than 20 *cm* dbh can be employed by marking the lower limit of measurement with a "ghost" stem in each growth group, and activating the prediction of recruitment for any growth group only when the marker (or ghost stem) attains 20 *cm* dbh.

Total recruitment was predicted as $N = 5.466 - 0.06469\ SBA + 1.013\ SQ$

where N is the number of recruits (stems/*ha/yr* at 20 *cm* dbh), SBA is stand basal area (m^2/ha of stems exceeding 20 *cm* dbh) and SQ is 1 on good sites and 0 on poor sites. On average, recruitment does not exceed 6.5 stems per hectare per annum, and does not occur where stand density exceeds 100 and 85 square metres per hectare basal area on good and poor sites respectively.

The proportion of recruitment in each growth group is predicted using a logistic function incorporating stand basal area, composition and site quality.

$$P_1 = (1 + e^{-2.407 - 0.005608\ SBA + 0.01105\ B_1 + 0.00464\ B_1\ SQ})^{-1}$$

$$P_2 = (1 + e^{-2.572 - 0.006756\ SBA + 0.11800\ B_2 - 0.06434\ B_2\ SQ})^{-1}$$

$$P_3 = (1 + e^{-1.761 - 0.008240\ SBA - 0.08076\ B_3 + 0.16610\ B_3\ SQ})^{-1}$$

$$P_4 = (1 + e^{-2.440 - 0.010690\ SBA + 0.16470\ B_4 - 0.06230\ B_4\ SQ})^{-1}$$

$$P_5 = (1 + e^{-0.655 - 0.024960\ SBA + 0.10630\ B_5 - 0.02621\ B_5\ SQ})^{-1}$$

where P_i is the proportion of the total recruitment as growth group i, SBA is stand basal area (m^2/ha of stems exceeding 20 *cm* dbh), B_i is the basal area of growth groups i, and SQ is 1 on good sites and 0 on poor sites. The use of the basal area of each growth group rather than the number of stems ensures robust predictions when inventory data derived from point sampling are projected. To ensure that these estimated proportions summed to exactly 1.0, the proportions were standardized:

$$P'_i = \frac{P_i}{\sum P}$$

The proportion of recruitment within each growth group assigned to any logging group is determined according to the composition of the corresponding stand fraction. The use of numbers of stems rather than basal area ensures reliable predictions despite the presence of useless veteran trees. Thus, for example, if it is determined that five percent of the growth group 1 stems in the existing stand are useless, then five percent of the predicted growth group 1 recruits will be assigned to that category. A similar procedure is followed to determine the volume group.

Example

Table 1 illustrates the operation of the cohort approach over a twenty-five year period. The inventory data was collected using horizontal point sampling with a 10 m2/ha optical wedge. Species code, diameter (cm dbhob) and merchantability (L indicates sawlog) were recorded.

The splitting of cohorts is evident in the first two cohorts during years one and two. The increment of cohort mean diameter is obvious, as is the reduction in stem numbers due to mortality. The flags, initially set at 15 *cm* (the lower limit of inventory), are removed when they reach 20 *cm*, after which recruitment commence. Recruitment may comprise several cohorts per year, according to the species indentity predicted.

POSSIBLE ENHANCEMENTS

In considering enhancements to growth models, it is important to bear in mind the requirements of yield forecasting: the model must be computationally efficient, deterministic and able to utilize normal inventory data.

Relative dominance and/or crown class provides a good indication of growth potential in many mixed forests, and could probably be usefully included in increment and mortality functions. Unfortunately, it is often very difficult to see the crowns of tall trees in rainforests, and it is probably impractical to consider such assessments in routine inventory.

However, there are several aspects in the current rainforest growth model which can and should, be enhanced. Site quality, species grouping and some of the prediction equations can all be improved. In the current model, site quality is rather subjectively determined as good or poor, and there is clearly considerable room for improvement. This is the subject of another paper at this converence (Vanclay 1988).

Species group

The current growth model provides four growth groups for commercial species, with a fifth group for most non-commercial species which were identified during inventory as miscellaneous. The use of "miscellaneous" during inventory should be restricted, and all species should be grouped according to growth characteristics. More growth groups will be required to accomodate species as diverse as palms and giant figs, as well as the commercial species.

The present model does not retain the original species identity of trees, but assigns them the group label. It would be useful to retain the original species identity.

Growth functions

The diameter increment functions will require revision as a result of the new site qualtity assessment and the revised species groupings. Vanclay (1988) has demonstrated the utility of overtopping basal area in modelling diameter increment, and this should be considered as a regressor variable when these functions are revised.

Although the current mortality functions appear reasonable, more data is required to confirm the mortality trend for large stems (those exceeding 100 *cm* diameter). The use of weighted non- linear least squares (Hamilton 1980) may offer some advantage in enabling more efficient use of data.

Time since disturbance (logging, cyclone, treatment) should be included in the equation to provide better prediction of damage- related mortality. Overtopping basal area and relative dominance could also be considered as possible regressor variables.

Since inventory now measures all stems down to and including 10 *cm* diameter, and the use of prism sampling precludes the use of the "constant pool" approach, the recruitment function should be revised to predict recruitment at 10 *cm* diameter rather than at 20 *cm* diameter.

The use of a time lag in determining the composition of recruitment should be investigated. Since stems which colonize and become established in gaps generally exist as advance growth prior to the disturbance, the pre-logging (or pre-cyclone) stand may have a greater influence on species composition than the post-disturbance stand. Accordingly, the use of a time lag of several years in determining the stand composition which influences recruitment should be investigated. time since logging and basal area removed should also be considered.

Other minor enhancements

During inventory stems are assessed as merchantable sawlogs or as useless, and the model assumes that this quality remains unchanged throughout the life of the stem. This is obviously incorrect, as it is evident that there is a gradual loss of merchantable stems to the useless category. Thus a function, similar to a mortality function, is required to predict this change in stem quality.

The distribution of increments (25% at 1.3 times and 75% at 0.9 times predicted increment) was subjectively determined, and these parameters should be estimated analytically.

Validation

Although casual inspection of long term predictions contrasted with actual data suggests that the rainforest growth model provides reasonably good forecasts, it has not been rigorously validated.

Validation should be seen as an essential component of growth model construction. It should not so much be concerned with the "correctness" of the mode, but rather with the inferences that may be drawn from using the model (Goulding 1979). A model which performs badly in validation tests should remain in use if it is the best available model. The validation results should be used to indicate areas for further research.

CONCLUSION

This brief review has illustrated that there are many suitable techniques of varying degrees of sophistication which can be used to provide objective yield forecasts for mixed tropical forests. The science of yield forecasting in these forests is still in its infancy, and further research and development is required. However, present results indicate that the cohort based approach is an efficient and reliable approach.

The Queensland rainforest growth model demonstrates a flexible modelling approach which may be readily adapted to other mixed/moist tropical forests.

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Table 1. Example of cohort model

Species	Inventory Data	Group SMLG	Year 0 Dbh	Year 0 N/ha	Year 1 Dbh	Year 1 N/ha	Year 2 Dbh	Year 2 N/ha	Year 3 Dbh	Year 3 N/ha	Year 10 Dbh	Year 10 N/ha	Year 25 Dbh	Year 25 N/ha
			Cohort List											
Cordeilia sublimis					41.97	1.85	42.30	1.85	42.64	1.84	44.99	1.88	49.96	1.81
Northern silky oak	NSO 41 L	322	41.50	7.39	41.83	5.54	42.26	1.38	42.59	1.38	44.94	1.38	49.92	1.36
							42.13	4.15	42.46	4.15	44.81	4.13	49.78	4.08
					49.92	1.29	50.22	1.29	50.51	1.28	52.57	1.23	56.81	1.14
Sloanea australis	BLA 49 L	374	449.50	5.20	49.79	3.88	50.09	3.86	50.38	3.84	52.44	3.70	56.68	3.41
Blush alder														
Cordeilia sublimis	NSO 26	492	26.50	18.13	26.80	18.10	27.08	18.07	27.36	18.05	29.35	17.86	33.67	17.51
Northern silky oak														
Canarium baileyanum	BRC 68	495	68.50	2.71	68.85	2.69	69.18	2.67	69.51	2.65	71.82	2.51	76.60	2.24
Brown cudgerie														
X. octandrum	MOB 42	495	42.50	7.05	42.82	6.99	43.13	6.94	43.43	6.89	45.56	6.52	50.11	5.81
Macintyre's boxwood	MOB 36	495	36.50	9.56	36.81	9.48	37.09	9.41	37.38	9.34	39.41	8.84	43.76	7.86
Miscellaneous	MIS 24	495	24.50	21.21	24.76	21.04	24.99	20.87	25.24	20.71	26.95	19.58	30.69	17.39
	MIS 16													
Miscellaneous	MIS 16	495	16.50	140.30	16.71	139.14	16.90	138.00	17.10	136.86	18.50	129.19	21.62	114.34
	MIS 16													
Fig. 1		2491	15.00		15.20		15.39		15.57		16.91		19.88	
Fig. 2		2492	15.00		15.22		15.43		15.64		17.15			
Fig. 3		2493	15.00		15.29		15.57		15.85		17.90			
Fig. 4		2494	15.00		15.19		15.36		15.54		16.79		19.59	
Fig. 5		2495	15.00		15.20		15.38		15.57		16.90		19.87	
Recruits Group 2		1322											20.11	.66
		1492											20.39	.38
Recruits Group 3		1493											22.21	2.29
		1493											21.24	3.42
		1493											20.31	3.56

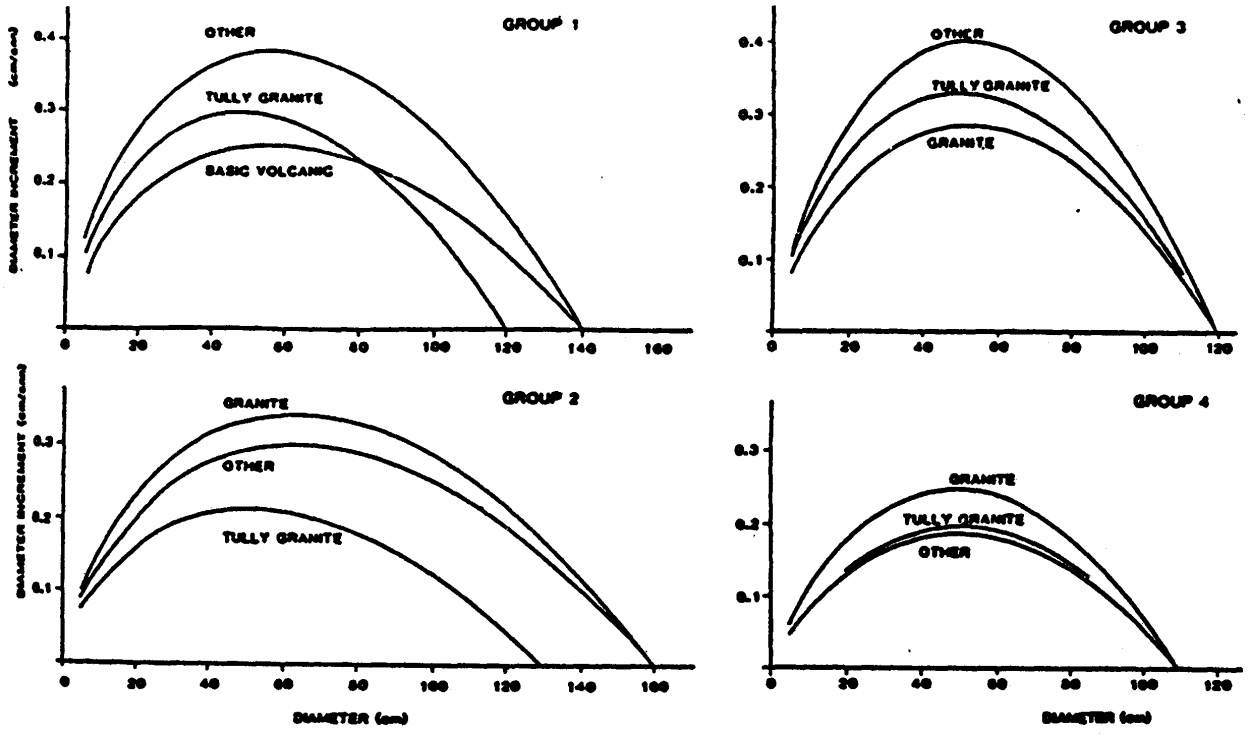
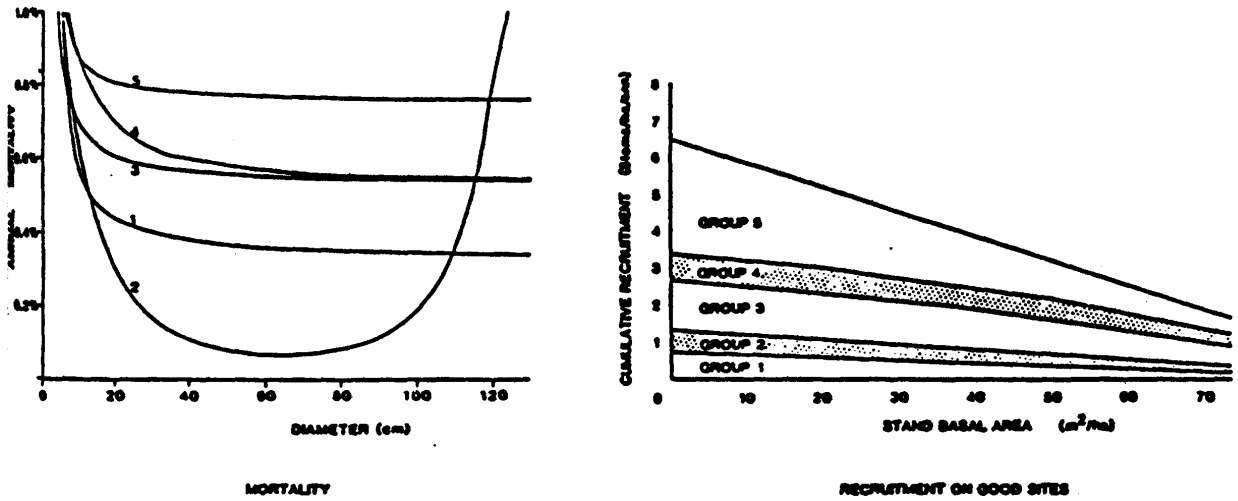


Figure 1. Diameter increment functions (Assuming 20 m^2/ha basal area and good site)



MORTALITY

RECRUITMENT ON GOOD SITES

Figure 2. Mortality and recruitment functions (Assuming 20 m^2/ha basal area)